

Weak Acids/ Base Calculation Tutorial

Reminder: pH of Strong Acids

$[H^+]$ or $[H_3O^+] = [\text{acid}]$ **strong** means 100% ionized/ dissociation
so, to find pH of 0.100 M HCl

$[H^+]$ or $[H_3O^+] = 0.100$ M

pH = 1.000

For weak acids $[H^+]$ or $[H_3O^+] \neq [\text{acid}]$

Eg.) What is pH of 0.10 M HF?

Look at equilibrium for **Weak Acid** HF

$HF(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + F^-(aq)$ or

K_{eq} = equilibrium constant

$$K_{eq} = \frac{[H_3O^+][F^-]}{[HF]}$$

$HF(aq) \leftrightarrow H^+(aq) + F^-(aq)$

$$K_{eq} = \frac{[H^+][F^-]}{[HF]}$$

For weak acids's K_{eq} is called **K_a** (**acid** ionization constant) - see acid table in book page 860 Table A-9 for list of K_a 's.

higher K_a = stronger acid

lower K_a = weaker acid

For Strong Acid's (eg. HCl) $K_{eq} = \frac{[H_3O^+][Cl^-]}{[HCl]}$ = called "very large!"

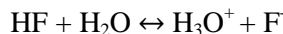
Calculations Using K_a (*Used for Weak Acids*)

$[H_3O^+]$ from K_a (pH from K_a)

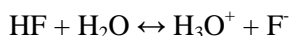
$[H_3O^+]$ from K_a and Original concentration (C_0)

eg.) Find the $[H_3O^+]$ in 0.10 M HF, $k_a = 3.5 \times 10^{-4}$

1. Write out equilibrium equation for *ionization*



2. Ice table



	HF	H_2O	H_3O^+	F^-
I	0.10		0	0
C	-x		+x	+x
E	0.10 - x		x	x

Water is not included in the k_a expression

3. K_a expression:

$$K_a = \frac{[H_3O^+][F^-]}{[HF]}$$

$$K_a = \frac{(x)(x)}{(0.1-x)}$$

$$K_a = \frac{x^2}{(0.1)}$$

Because K_a is so small, $< 1.0 \times 10^{-4}$, the x is insignificant and can be thrown out

4. Substitute:

5. Solve for x ($[H_3O^+]$)

$$K_a = \frac{x^2}{(0.1)}$$

$$\text{So } x^2 = 0.10 K_a$$

$$[H_3O^+] = x = \sqrt{0.1 K_a}$$

$$[H_3O^+] = x = \sqrt{0.1(3.5 \times 10^{-4})}$$

$$[H_3O^+] = 5.9 \times 10^{-3} \text{ M}$$

$$\text{pH} \approx -\log[5.9 \times 10^{-3}] \rightarrow 2.23$$

~ Check assumption (we see that this is quite small compared to 0.10)

NOTE: Ions which act as acids can come from compounds.

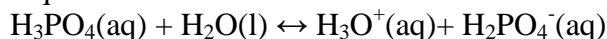
What If the K_a is not $<1.0 \times 10^{-3}$?

Pre-AP

For weak acids $[H^+]$ or $[H_3O^+] \neq [\text{acid}]$

Eg.) What is pH of 0.50 M H_3PO_4 ?

Look at equilibrium for **Weak Acid HF**



K_{eq} = equilibrium constant

$$K_{eq} = \frac{[H_3O^+][H_2PO_4^-]}{[H_3PO_4]}$$

K_a (**acid** ionization constant) - see acid table in book page 860 table A-9 for list of K_a 's.

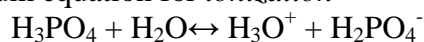
Calculations Using K_a (*Used for Weak Acids*)

$[H_3O^+]$ from K_a (pH from K_a)

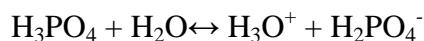
$[H_3O^+]$ from K_a and Original concentration (C_o)

eg.) Find the $[H_3O^+]$ in 0.10 M H_3PO_4

1. Write out equilibrium equation for *ionization*



2. Ice table



$H_3PO_4 + H_2O \leftrightarrow H_3O^+ + H_2PO_4^-$				
I	0.50		0	0
C	-x		+x	+x
E	0.50 - x		x	x

3. K_a expression:

$$K_a = \frac{[H_3O^+][F^-]}{[HF]}$$

$$K_a = \frac{(x)(x)}{(0.5-x)}$$

$$K_a = \frac{x^2}{(0.5-x)}$$

Because K_a is bigger than 1.0×10^{-4} , the x is **significant**

4. Substitute:

5. Solve for x ($[H_3O^+]$)

$$7.08 \times 10^{-3} = \frac{x^2}{(0.5-x)}$$

$$\text{So } x^2 = 0.10 K_a$$

$$3.54 \times 10^{-3} - 7.08 \times 10^{-3}x = x^2$$

$$x^2 + 7.08 \times 10^{-3}x - 3.54 \times 10^{-3} = 0$$

$$\text{Use: } x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \text{ where } ax^2 + bx + c = 0$$

$$x = 0.05606 \text{ or } -0.06314$$

$$x ([H_3O^+]) = 0.05606$$

$$\text{so pH} \approx -\log[0.05606] \rightarrow 1.25$$

Pre-AP

Practice:

Complete on a separate sheet of paper, show all work.

1. What is the $[\text{H}_3\text{O}^+]$ of a 0.01 M benzoic acid solution, $K_a = 6.3 \times 10^{-5}$?
2. A 0.16 M NH_4^+ ($K_a = 5.6 \times 10^{-10}$) solution has what pH?
3. Calculate the pH of 0.10 M solution of hypochlorous acid, HOCl , $K_a = 2.9 \times 10^{-8}$
4. If 0.04500 M acetic acid ($K_a = 1.75 \times 10^{-5}$) is in a jar, what is the pH?
5. Calculate the H_3O^+ ion concentration **and** the pH of acetic acid solutions with the following concentrations:
 - a) 1.0 M
 - b) 0.10 M
 - c) 0.01 M.
6. Calculate the H_3O^+ concentration in a 0.035 M solution of chlorous acid (HClO_2). (need to use quadratic)
$$\text{HClO}_2 \leftrightarrow \text{H}^+ + \text{ClO}_2^- \quad K_a = 1.2 \times 10^{-2}$$
7. The K_a of Phosphorous acid, H_3PO_3 , is **6.31×10^{-2}** . What is the equilibrium $[\text{H}^+]$ in a 0.150M solution of Phosphorous acid? (need to use quadratic)
8. Consider a solution of 0.0500 M formic acid ($K_a = 1.8 \times 10^{-4}$), what is the pH of the solutions? (use quadratic!)
9. Cyanic acid is a weak monoprotic acid. If the initial concentration of cyanic acid is 0.150 M and the equilibrium concentration of H_3O^+ is 4.8×10^{-2} M, calculate K_a for cyanic acid.
10. Uric acid is a weak acid. If the initial concentration of uric acid is 0.110 M and the equilibrium concentration of H_3O^+ is 3.4×10^{-2} M, calculate K_a for uric acid.